10

Interim Report

ORSER-SSEL Technical Report 12-75

COMPARISON OF SKYLAB AND LANDSAT LINEAMENTS WITH JOINT ORIENTATIONS IN NORTHCENTRAL PENNSYLVANIA *

W. S. Kowalik

ERTS Investigation 082
Contract Number NAS 5-23133

Skylab EREP Investigation
Contract Number NAS 9-13406

INTERDISCIPLINARY APPLICATION AND INTERPRETATION OF ERTS AND EREP DATA WITHIN THE SUSQUEHANNA RIVER BASIN

Resource Inventory, Land Use, and Pollution

Office for Remote Sensing of Earth Resources (ORSER)
Space Science and Engineering Laboratory (SSEL)
Room 219 Electrical Engineering West
The Pennsylvania State University
University Park, Pennsylvania 16802

Principal Investigators:

Dr. George J. McMurtry
Dr. Gary W. Petersen

Date: July 1975

*Author identified significant results.

COMPARISON OF SKYLAB AND LANDSAT LINEAMENTS WITH JOINT ORIENTATIONS IN NORTHCENTRAL PENNSYLVANIA

W. S. Kowalik

Office for Remote Sensing of Earth Resources
The Pennsylvania State University

Support for the work reported here was provided by NASA Contract NAS 5-23133 as a part of the ERTS-1 Program and NASA Contract NAS 9-13406 as part of the Skylab EREP Program.

A geometric and/or mechanical relationship between joints, fracture traces[1], and lineaments[2] has been inferred (Gold, et al., 1973; Gol'braikh, et al., 1968; and Haman, 1964). In order to study the possible relationships between linear features at different scales, linear topographic and tonal features in parts of eight counties on the Allegheny Plateau (Figure 1) were mapped and interpreted from a Skylab-4 photograph[3] and part of a Landsat-1 infrared image[4].

Immediately adjacent to the area considered here, Lattman and Nickelsen (1958) have shown that joint directions are typically subparallel to the fracture traces and that the fracture traces peak from N20°W to N45°W near Houtzdale. Elsewhere, in similarly undeformed strata, Hough (1960) and Boyer and McQueen (1964) have shown that joints lie subparallel to fracture traces; while Isachsen (1973) noted that many lineaments also parallel joint trends on the Allegheny Plateau. Lineaments in the area studied here also lie subparallel to joints and to the fracture traces identified by Lattman and Nickelsen (1958). This subparallel orientation of joints, fracture traces, and lineaments suggests a genetic relationship for these features on the Allegheny Plateau.

Procedure

Positive transparencies of the Landsat and Skylab images were viewed on a light table and relatively short lineaments were mapped. The length distributions of the Landsat and Skylab lineaments (Figure 2) are similar except for the larger number of shorter Skylab lineaments. This indicates that essentially the same population of lineaments were sampled in each case.

---

[1] Linear features less than 1.5 km long (Lattman, 1958).

[2] Linear features greater than 1.5 km long (Lattman, 1958).

[3] S190B, 4 Jan 1974, Roll 91, Frame 324, color positive, 1:517,000 scale.

[4] Scene 1459-15221, 25 Oct 1973, Channel 7, 1:989,000 scale.

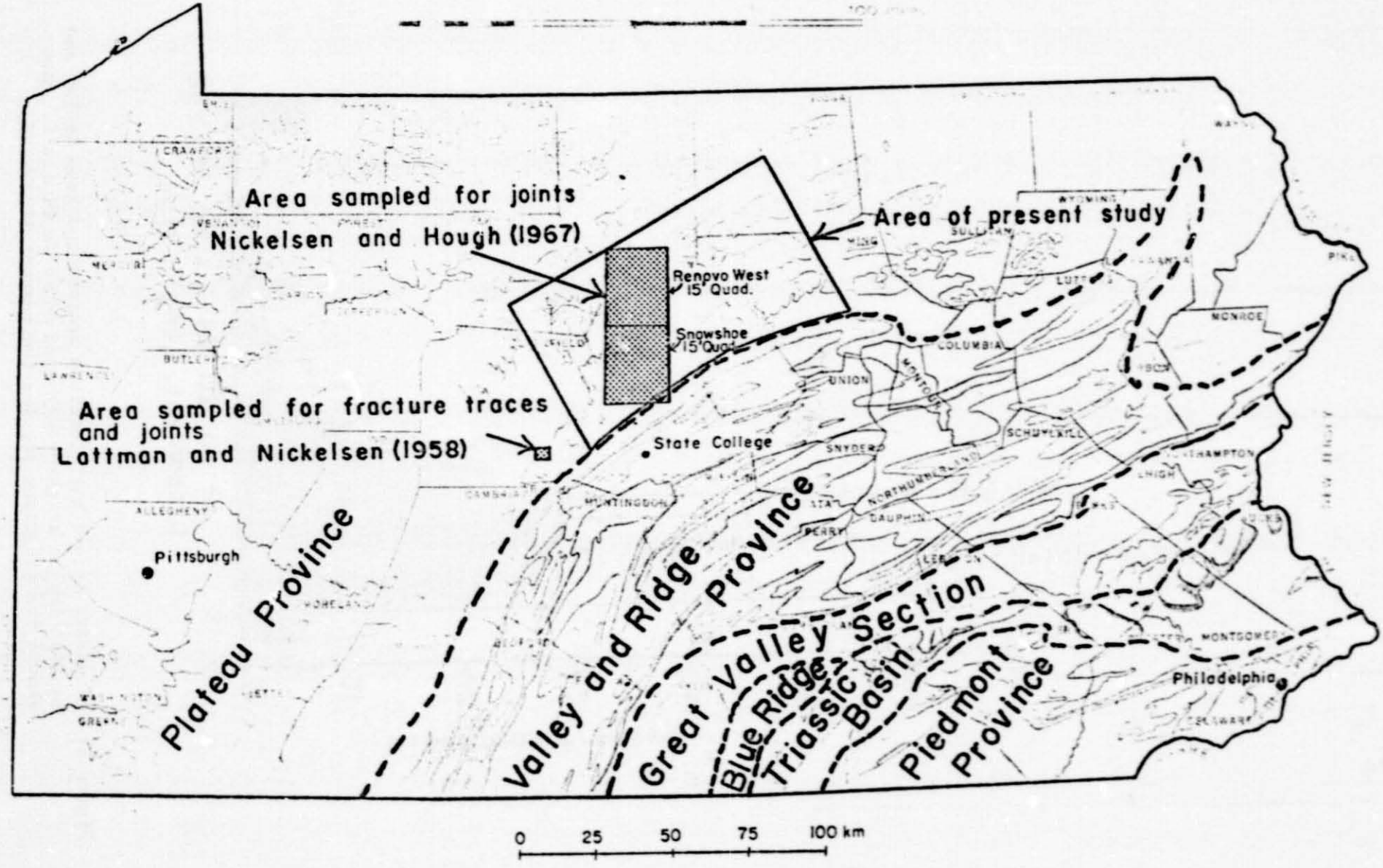

Figure 1: Location of areas in central Pennsylvania referred to in this report. The base map is the geologic map of Pennsylvania.

3

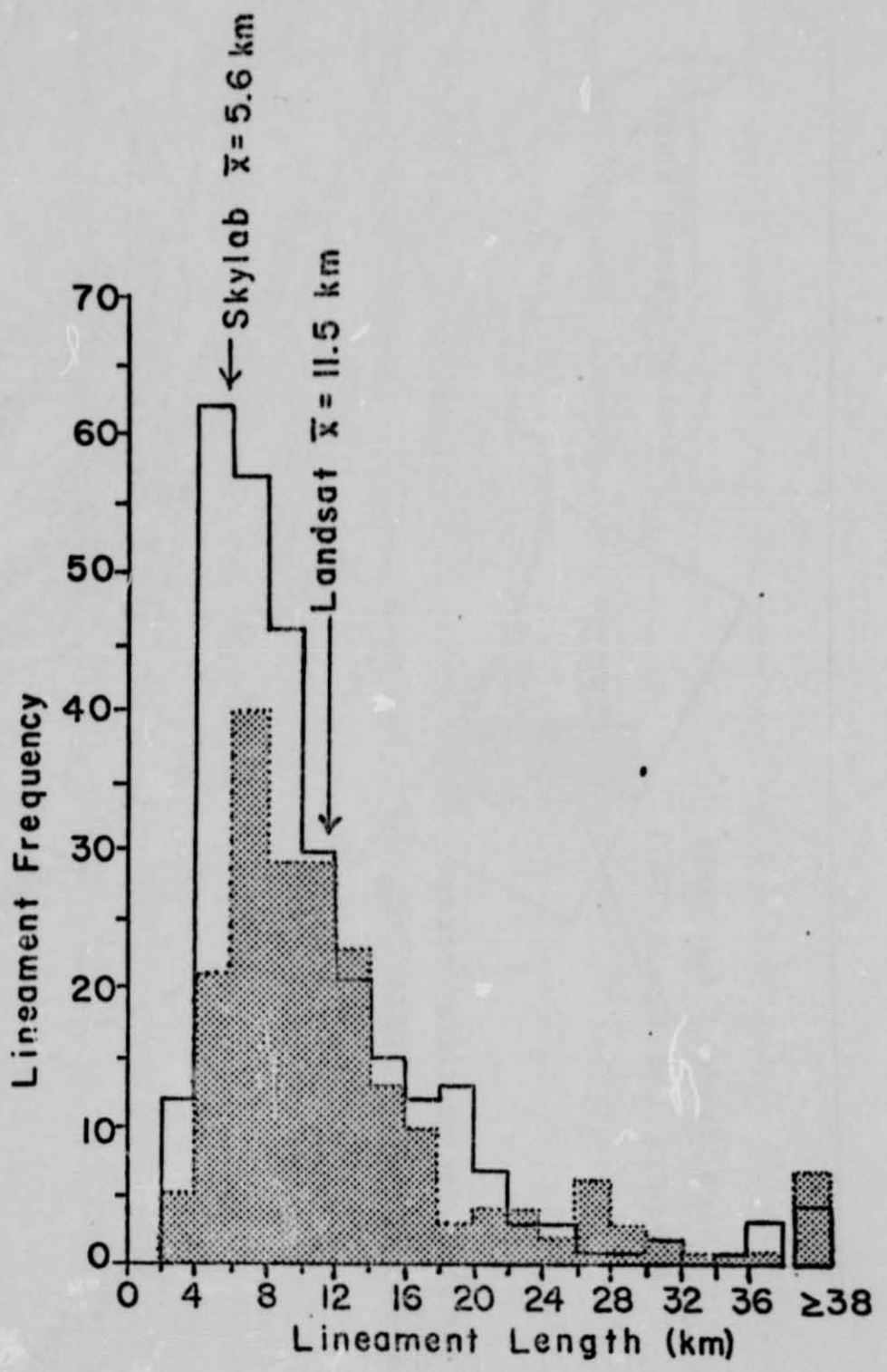

Figure 2: Lineament length distributions intrepreted from Skylab and Landsat images in the study area shown in Figure 1. The shaded distributions are for the Landsat lineaments.

The lineaments were rated on a three-class ordinal scale of degree of expression, and on a purely descriptive three-level classification of lineament type (major streams, minor streams, or tonal lineaments). The majority of lineaments are mapped from alignments of stream channel segments. Orientation of lineaments were summarized using modified versions of Podwysocki's (1974) programs.

Biased Sampling

Wise (1968) has noted the lineament sampling bias caused by illumination from a point source. He showed that maximum enhancement of lineaments occurred when the incident light completely illuminates one valley wall and just grazes the opposite wall. The enhancement of any lineament is thus a function of valley wall slope and the orientation of the lineament with respect to the illumination azimuth and vertical illumination angle. The conditions for maximum enhancement are illustrated in Figure 3. Note that if the inclination angle exceeds the valley slope, no shadow enhancement occurs.

The steepest valley walls in the area considered here are close to 32°. Outcrops of the resistance Pocono and Pottsville units approach 90° for a few tens of feet in valley walls. It is doubtful that these cliffs cause much shadowing. The lineaments enhanced to maximum visibility on the Skylab photograph (20° sun elevation) therefore, should theoretically be oriented between 40° and 90° to the illumination direction. On the Landsat image (32° sun elevation), maximum enhancement should occur for lineaments oriented approximately 90° to the illumination direction. Conversely, lineaments should be relatively obscured at angles from 0° (parallel) and up to about 40° to the sun azimuth on the Skylab photograph and at nearly all angles -- but especially parallel to the sun azimuth -- on the Landsat image.

Figure 4 presents the total length versus orientation histograms for the Skylab and Landsat lineaments interpreted in the area. The Landsat histogram shows a double NW peak and the Skylab histogram shows a single broad peak at that position. The double Landsat peak appears to be primarily a function of the lack of lineaments parallel to the sun azimuth. The Skylab histogram also shows a decrease of lineaments near its sun azimuth.

The direction of maximum enhancement of the Landsat lineaments lies near the bedrock strike direction, near which lineaments were purposefully not drawn. The major N-NW Skylab peak lies within the zone of optimum enhancement of lineaments on the Skylab photograph. It appears that this peak is real because the Skylab histogram does not show a symmetrical peak to the East of the mean strike direction where one one might also be expected as a result of lineament enhancement.

Current research by this author suggests there is a bias against detecting lineaments parallel to the scane lines on Landsat images. The Skylab photograph, which lacks scan lines, also shows a decrease parallel

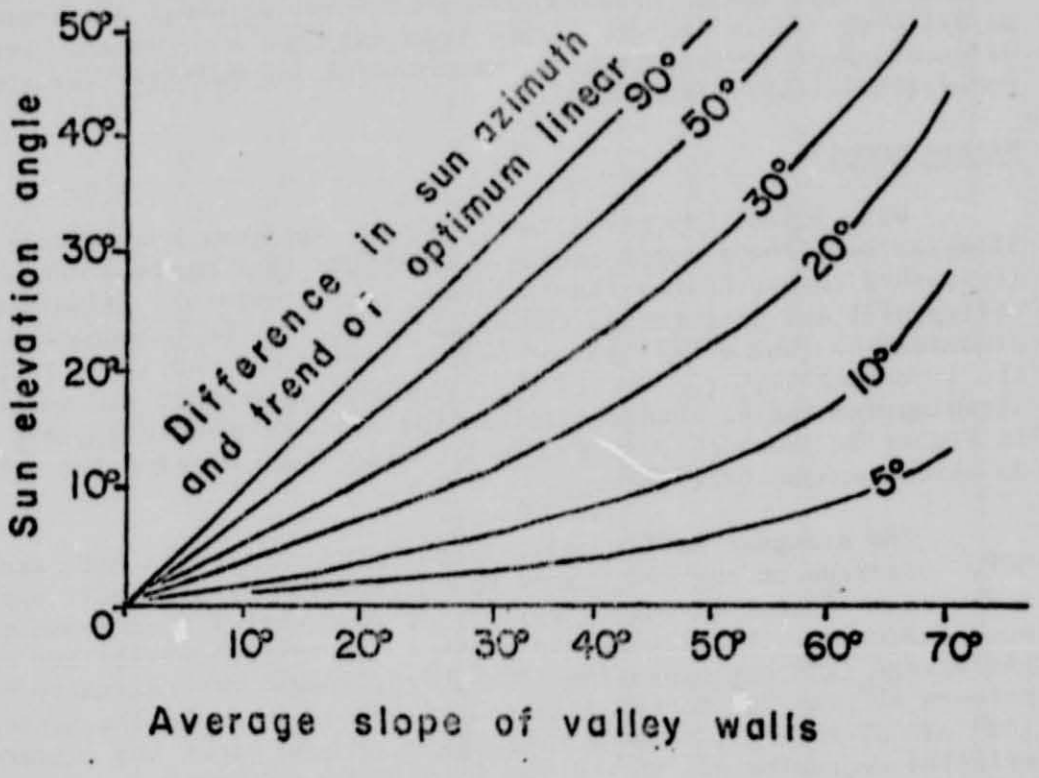

Figure 3: Conditions for maximum enhancement of a topographic linear by shadow techniques. (After Wise, 1968)

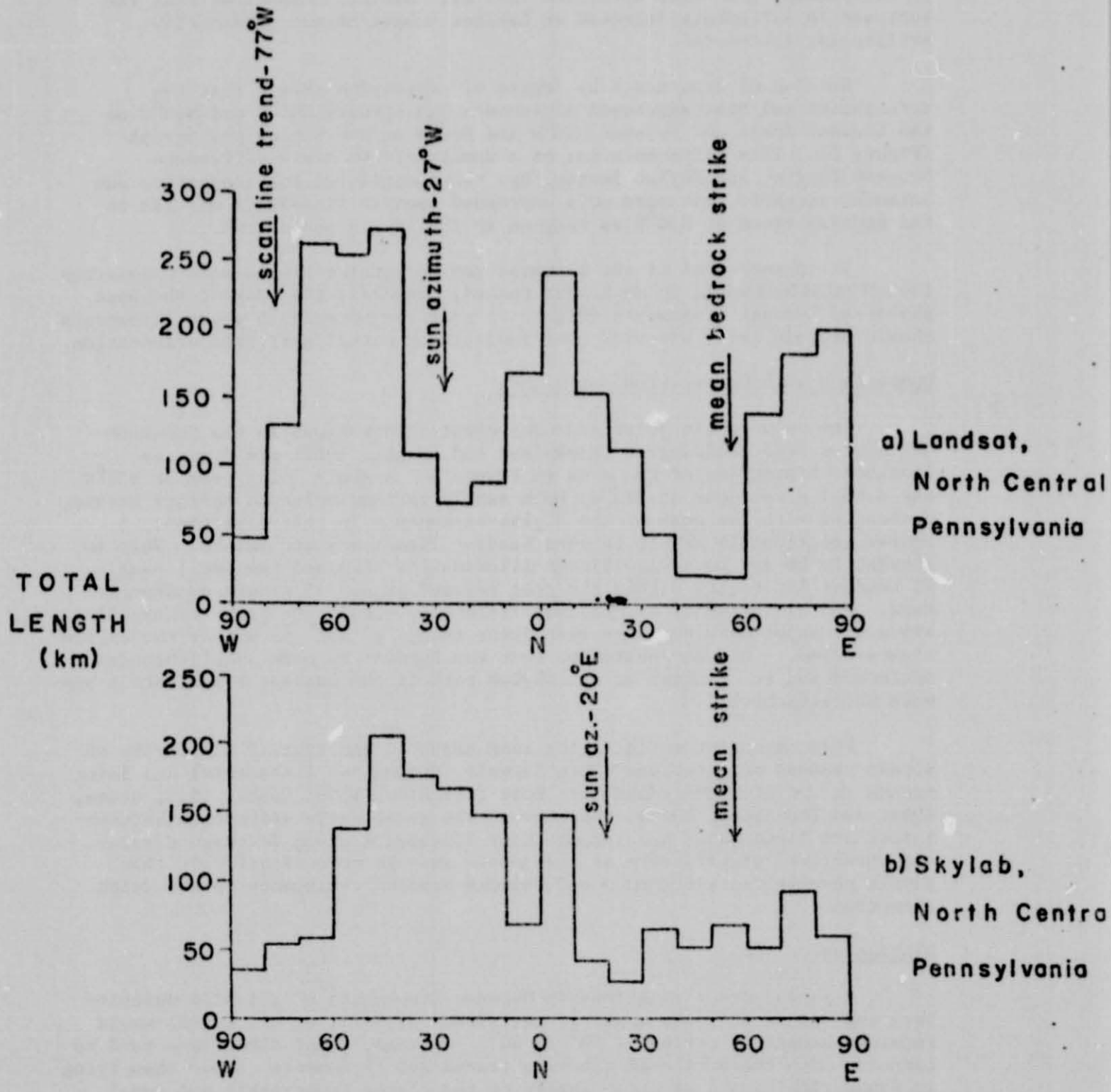

Figure 4: Summed length versus orientation histograms for Landsat (a) and Skylab (b) lineament interpretations.

to the Landsat scan line direction (N77°W), however, suggesting that the decrease in lineaments detected on Landsat images is not necessarily artifically introduced.

Sorting of lineaments by degree of expression showed that the straightest and best expressed lineaments lie between N40°W and N60°W on the Landsat image and between N10°W and N50°W on the Skylab photograph (Figure 5). This difference may be a result of the scale difference between Landsat and Skylab images, but the position of the respective sun azimuths suggests that more well expressed Landsat lineaments may lie in the general trend of N30°W as they do in the Skylab photograph.

It appears that if the illumination and strike biases were eliminated, the orientations would be much less peaked. However, the peak of the best expressed Landsat lineaments (Figure 5) near the sun azimuth where lineaments should be relatively obscured must indicate an actual perferred orientation.

Comparison with Orientations of Joints

The major shale joint and coal cleat orientations in the Snowshoe and Renova West Quadrangles (Nickelsen and Hough, 1967) are drawn on lineament histograms of the area in Figure 6. A shale joint peak at N35°W and a coal cleat peak at N25°W, both nearly perpendicular to bedrock strike, correspond with the peak of the Skylab lineaments in that direction. A poorer relationship exists between Landsat lineaments and joints. This is thought to be due to a significant illumination bias and the small sample of Landsat lineaments within the area covered by the 15 minute quadrangle maps. The histogram of all Landsat lineaments within the area (Figure 4) shows the major peak near the main joint trends of N35°-45°W over the entire area studied. (One may postulate that the Landsat NW peak should broaden northward and be similar to the Skylab peak if the Landsat illumination bias were not present.)

This agreement reflects the long observed and typical similarity of stream channel orientations (here largely forming the lineaments) and joint trends in undisturbed sedimentary rock (Van Hise, 1895; Hobbs, 1905; Stone, 1964; and Thornbury, 1966). Because of the great scale difference between joints and lineaments, and because many lineaments cross drainage divides, the structural significance of lineaments must be more significant than simple parallelism with joints and reduced erosion resistance in the joint direction.

Discussion

A second order relationship between lineaments of the size detected here and joints of lower order as envisioned by Gold, et al. (1973) would require changes in strike of 20° to 60°. Instead, joint directions tend to coincide with the strike of fracture traces and lineaments rather than lying in symmetrical peaks at acute angles to the linear topographic and tonal features. It seems likely that in undisturbed strata, joints and lineaments are differently scaled affects of a continuous range of natural linears of similar origin. It is notable that body forces have been invoked to explain the origin of joints (Hodgson, 1961), as well as of fracture traces

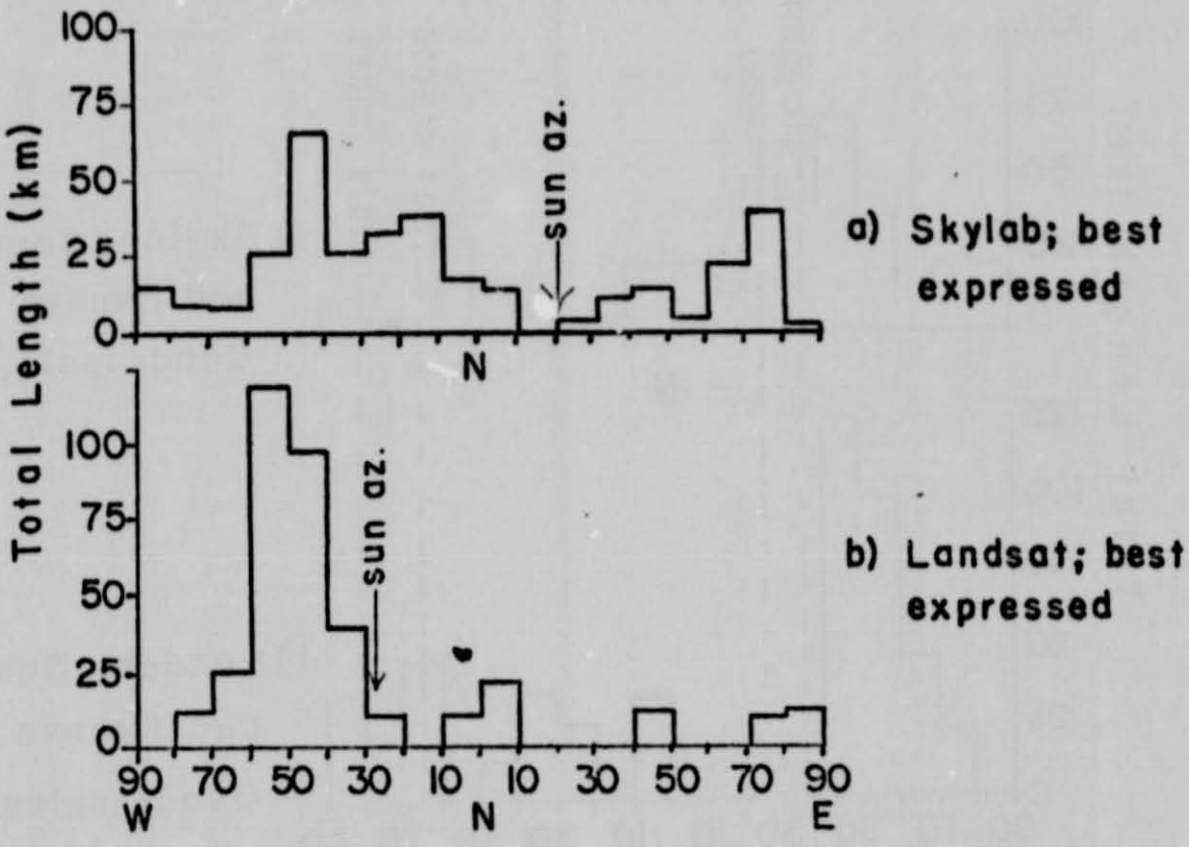

Figure 5: Summed length versus orientation histograms for the most linear and best expressed Skylab (a) and Landsat (b) lineament.

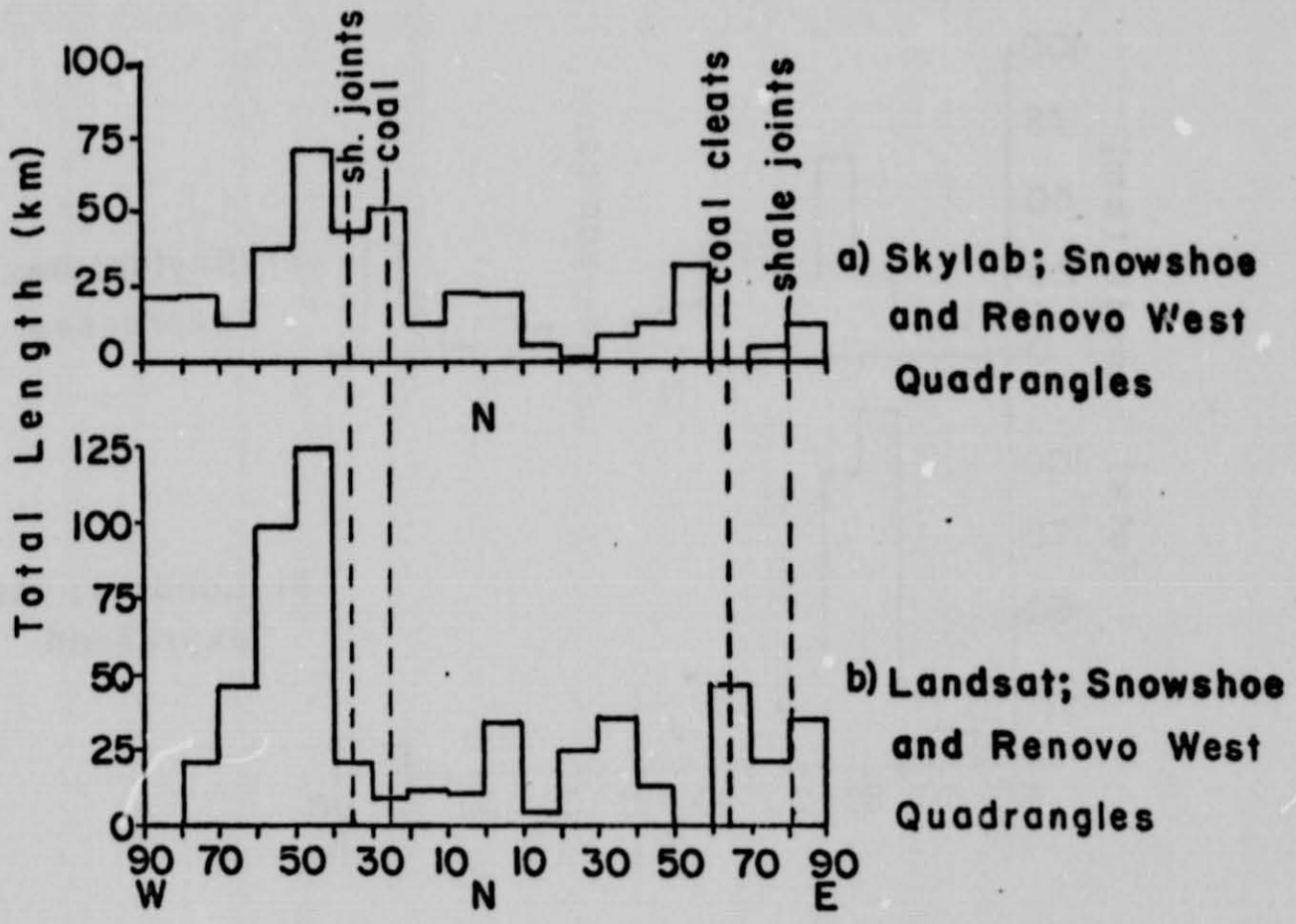

Figure 6: Summed length versus orientation histograms for lineaments in the Snowshoe and Renova West 15-minute quadrangles for Skylab (a) and Landsat (b) data. (Joint and cleat orientations are from Nickelsen and Hough, 1967.)

(Blanchet, 1957) and of lineaments (Blanchet, 1957; Gold, et al., 1974). Price (1966) pointed out that several workers have noted an inverse relationship between joint frequency and bed thickness, holding other factors such as lithology and degree of tectonic deformation constant. Lineaments may be produced by body forces acting on mega-layers of the earth's crust in much the same fashion that fracture traces may be produced in structurally coherent thicknesses of strata. These same forces, at much higher frequencies, may also provide joints parallel to the larger lineaments in individual lithologic units.

Summary

The histogram peaks of lineaments mapped from the Skylab photograph at a scale of 1:517, 000, lie subparallel, within 20°, to major shale joints and coal cleats on the part of the Allegheny Plateau considered here. The Landsat lineaments, mapped at 1:989,000 are biased by illumination and scan line directions. While there is an illumination bias in the Skylab photograph, its direction does not coincide with the main transverse lineament trend, thus providing an independent assessment of the illumination direction bias. The coincidence in direction regardless of scale of the linear features, in the area considered here, suggests a mechanical relationship between joints, fracture traces and lineaments which is more consistent with a tensional model than a shear model of origin.

REFERENCES

Blanchet, P. H. (1957) Development of Fracture Analyses as Exploration Methods. Bull. Am. Assoc. Petrol. Geologists. 41:1748-1759.

Boyer, R. E. and J. E. McQueen (1964) Comparison of Mapped Rock Fractures and Airphoto Linear Features. Photogram. Engineering. 30:630-635.

Gol'braikh, I. G., V. V. Zabaluyev, and G. R. Mirkin (1968) Tectonic Analyses of Megajointing: A Promising Method of Investigating Covered Territories. Internat. Geol. Review. 8(9):1009-1016.

Gold, D. P., R. R. Parizek, and S. S. Alexander (1973) Analysis and Application of ERTS-1 Data for Regional Geological Mapping. Symposium on Significant Results Obtained from the Earth Resources Technology Satellite - 1. 1:231-246.

Gold, D. P., S. S. Alexander, and R. R. Parizek (1974) Application of Remote Sensing to Natural Resources and Environmental Problems in Pennsylvania. Earth and Mineral Sciences. 43(7):49-53.

Haman, P. J. (1964) Geomechanics Applied to Fracture Analysis on Aerial Photographs. Western Canadian Research Publication of Geology and Related Sciences, Serial No. 2.

Hobbs, W. H. (1905) Examples of Joint Controlled Drainage from Wisconsin and New York. Jour. Geology. 13:363-374.

Hodgson, R. A. (1961) Regional Study of Jointing in the Comb Ridge - Navajo Mountain Area, Arizona and Utah. Bull. Am. Assoc. Petrol. Geologists. 45:1-38.

Hough, V. N. D. (1960) Photogeologic Techniques Applied to the Mapping of Rock Joints. West Va. Geol. and Econ. Survey Report of Investigation 19.

Isachsen, Y. W. (1973) Spectral Geological Content of ERTS-1 Imagery Over a Variety of Geological Terranes in New York State. Proceedings of Symposium on Management and Utilization of Remote Sensing Data, Sioux Falls, October 29 - November 1. pp. 342-363.

Lattman, L. H. (1958) Technique of Mapping Geologic Fracture Traces and Lineaments on Aerial Photographs. Photogram. Engineering. 24(4):568-576.

Lattman, L. H. and R. P. Nickelsen (1958) Photogeologic Fracture Trace Mapping in Appalachian Plateau. Bull. Am. Assoc. Petrol. Geologists. 42:2238-2245.

Nicklesen, R. P. and V. N. D. Hough (1967) Jointing in the Appalachian Plateau of Pennsylvania. Bull. Geol. Soc. America. 78:609-629.

Podwysocki, M. H. (1974) Fortran IV Programs for Summarization and Analysis of Fracture Trace and Lineament Patterns. NASA - Goddard Space Flight Center Document X-644-74-3.

Price, N. J. (1966) Fault and Joint Development in Brittle and Semi-Brittle Rock. The Commonwealth and International Library, Pergamon Press, Oxford.

Stone, J. E. (1964) Drainage Patterns Controlled by Systematic Joints in Glacial Drift. Geol. Soc. Am. Special Paper 76. pp. 159-160.

Thornbury, W. D. (1966) Principles of Geomorphology. J. Wiley and Sons, N. Y.

Van Hise, C. R. (1895) Origin of Dells of Wisconsin. Transactions of Wisconsin Academy of Science, Arts, Letters. 10:556-560.

Wise, D. U. (1968) Regional and Sub-Continental Size Fracture Systems Detectable by Topographic Shadow Techniques. Geol. Surv. Canada Paper 68-72. pp. 175-199.